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(54) Arrangement consisting of a photodiode and an optical fiber

(57) In optical data communications, optical fibers are used as light guides, and photodiodes as receivers. The coupling between fiber and photodiode is of great importance. Conventionally, mechanical parts are used to hold the fiber and the photodiode in an optimum position relative to each other. These parts must be formed with high precision, so that their mass production is complex and expensive.

In the arrangement according to the invention, a photodiode (PD) contacted by contact wires (GW) has its photosensitive surface (PS) attached directly to one fiber end by means of an optically transparent adhesive (CG). The fiber (OF) is fastened on a circuit board (BD) to which the contact wires (GW) of the photodiode (PD) are connected. The adhesive joint (CG) between photodiode (PD) and fiber (OF) represents the only mechanical attachment of the photodiode (PD).

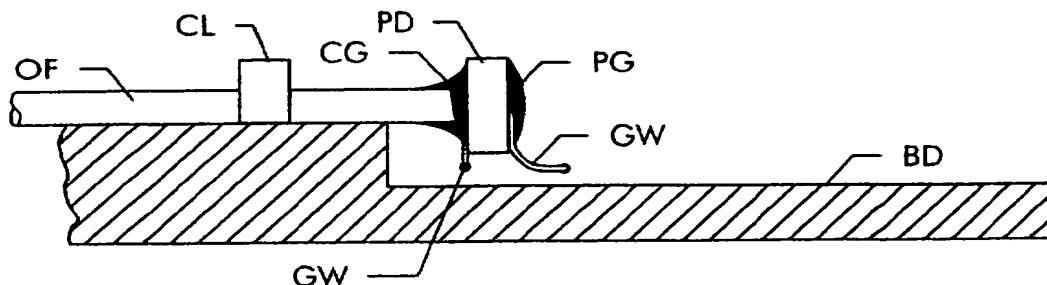


Fig. 3

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Description

[0001] This invention relates to an arrangement consisting of a photodiode and an optical fiber, to a circuit board on which a fiber with a photodiode is fastened and which contains a control circuit for the photodiode, and to a method of coupling an optical fiber to a photodiode.

[0002] In optical data communications, optical fibers are used as light guides. Receivers are photodiodes to which one end of the light-guiding fibers is coupled. The coupling between fiber and photodiode is of great importance. Conventionally, mechanical parts are used to hold the fiber and the photodiode in an optimum position relative to each other.

[0003] U.S. Patent 6,017,681 discloses an arrangement in which the photodiode and the fiber are fixed to a substrate. A photosensitive material is then deposited between the fiber and the photodiode, and during the setting of the material, light is applied from the fiber to the material. This changes the optical properties of the photosensitive material in such a way that it forms a coupler between fiber and photodiode.

[0004] The mechanical parts that hold the photodiode and the fiber in position relative to each other must be formed with high precision because the permissible alignment tolerances are in the range of a few micrometers. This makes the mass production of the mechanical parts complex and expensive.

[0005] It is therefore an object of the present invention to provide an arrangement consisting of a photodiode and an optical fiber wherein good coupling is achieved in a simple manner. Another object of the invention is to provide a circuit board equipped with a photodiode and a control circuit for the photodiode on which an optical fiber is fastened which is coupled to the photodiode in a simpler manner. A further object of the invention is to provide a less complex method of coupling a fiber to a photodiode.

[0006] These objects are attained by the features of claims 1, 8, and 9, respectively. Further developments of the invention are apparent from the dependent claims.

[0007] Particular advantages of the invention are that the dependence on temperature variations is reduced, that the arrangement is free of mechanical stress, that compared with conventional arrangements, photosensitivity is increased by about 10%, that very short leads can be used, which is important for applications at high bit rates (gigahertz range), and that the arrangement can be made very compact. The invention is also ideally suited for circuits with two or more photodiodes and fibers.

[0008] Two embodiments of the invention will now be explained with reference to the accompanying drawing, in which:

Fig. 1 shows a photodiode with leads;
Fig. 2 is a top view of an arrangement with a photo-

diode and a fiber on a circuit board;
Fig. 3 is a section taken along line III-III of Fig. 2;
Fig. 4 is a top view of an arrangement with a photodiode and a fiber on a circuit board in a second embodiment; and
Fig. 5 is a section taken along line V-V of Fig. 4;

[0009] The photodiode PD shown in Fig. 1 is a semiconductor chip that is contacted on both sides by gold wires GW. On one side, photodiode PD has a photosensitive surface PS with a diameter of the order of 30 to 80 µm. The remaining surface of the chip has a metal layer ML deposited thereon which acts as a contact area. On the other side of the chip, a metal layer is deposited over the entire surface. Gold wires GW are 18 µm in diameter and are connected to a solder pad SB on metal layer ML.

[0010] To fabricate the arrangement, in a first step, the gold wires are soldered to the metal layer of the semiconductor chip. Next, the photodiode is aligned to the fiber end, e.g., on a three-axis micrometric translation stage, and its photosensitive surface is attached to the fiber end using an optically transparent adhesive. The photodiode and the fiber are held in place until the adhesive has set. To set the adhesive, in the embodiment, it is irradiated with ultraviolet light. Finally, the fiber is fastened on a circuit board, and the gold wires of the photodiode are connected to the circuit board.

[0011] Fig. 2 shows the finished circuit board BD with the fiber OF fastened thereon in a top view. A clamp CL holds fiber OF on circuit board BD. Photodiode PD is attached to the end face of fiber OF by a droplet of optically transparent adhesive CG. Gold wires GW are soldered to both sides of photodiode PD and connected to circuit board BD. The adhesive droplets CG and PG also serve to fix the gold wires GW and protect them from being ripped off. Further electronic semiconductor components C1, C2, C3 are mounted on circuit board BD. They form the control circuit for photodiode PD and detect electric pulses which are generated by photodiode PD on the occurrence of light in fiber OF, and which are sent over the gold wires GW to the control circuit. Such control circuits are familiar to those skilled in the art, so that they need not be dealt with here.

[0012] Photodiode PD is mechanically attached only to the end face of optical fiber OF, namely by adhesive joint CG, and is not mechanically attached to the circuit board. As a result, the coupling between fiber OF and photodiode PD is free of mechanical stress, and temperature-induced length changes will not result in a misalignment between photodiode PD and fiber OF. The photodiode is electrically connected to the circuit board via the gold wires GW.

[0013] Fig. 3 shows a section through the circuit board taken along line III-III. Optical fiber OF is fastened on a step of circuit board BD with clamp CL. Photodiode PD has been attached to the end of the fiber with adhesive. The adhesive joint is designated CG. On the side of the

photodiode remote from the fiber, another adhesive droplet PG has been applied to stabilize the contact wire GW and protect it from being ripped off.

[0014] It can be clearly seen that the photodiode is not mechanically attached to circuit board BD itself, but projects freely over the circuit board. The only mechanical attachment of photodiode PD is adhesive joint CG.
[0015] The adhesive used in the embodiment is a cationic epoxy resin that sets by the action of ultraviolet light. Such an adhesive is commercially available under the designation VITRALIT™ 1505. It has a refractive index of 1.517 and is sufficiently transparent in the wavelength range of 1300 nm to 1500 nm. Moreover, the adhesive is temperature-resistant in the range of -40°C to +80°C, which generally includes the permissible temperature range for the operation of telecommunications equipment. Furthermore, the adhesive provides electric isolation, so that the soldered joints of the photodiode, which are covered with the adhesive, are protected against inadvertent short circuits. As a result, aligning the fiber with the photodiode bonded thereto relative to the circuit board is uncritical. Last but not least it is important that the adhesive does not lase in the wavelength range used, i.e., that it does not emit light as a result of the pumping action of laser light applied through the fiber.

[0016] Advantageously, the adhesive has a surface tension through which self-alignment of the adhesive-wetted chip to the fiber takes place.

[0017] For the adhesive bonding, the fiber and the chip are aligned with about 10µm accuracy using a three-axis micrometric translation stage. The adhesive may be applied prior to the aligning procedure, since it only sets by the action of ultraviolet light. If an adhesive with a surface tension sufficient for self-alignment is used, the alignment between chip and fiber may be performed less accurately.

[0018] Before the photodiode is bonded to the fiber end, the latter should be cleaned with alcohol or another suitable solvent. Advantageously, the fiber end may be etched or ground to ensure better adhesion of the adhesive. For the chip, no specific pretreatment is necessary, but it is advantageous to clean the chip, for example in an ultrasonic bath using a suitable solvent.

[0019] In the embodiment, the fiber is fastened on the circuit board with a clamp and it is important to note that the clamp CL is only shown schematically and has for the sake of simplicity not the right scale and dimensions compared to the other components shown in Figures 2 and 3. Any other type of fastening is also possible, such as gluing the fiber in a corresponding groove in the circuit board.

[0020] In this embodiment, the photodiode is a chip contacted on both sides which is commercially available under the designation A1911DC. It is also possible to use photodiodes of other types, such as photodiodes mounted on a small carrier which have only one contact wire and where a second connection is made via the

carrier. In that case, the photodiode will be bonded to the fiber end together with the carrier.

[0021] A second embodiment shown in figures 4 and 5 illustrates such a photodiode mounted on a small carrier - a so-called submount. Figure 4 shows a top view on the second embodiment. Same components are depicted with same reference signs as in figures 2 and 3. Photodiode PD is soldered to submount SM and bonded with gold wire GW to submount SM. The submount soldered photodiode is glued at the end of optical fiber OF with UV polymerization cationic epoxy resin CG. The optical fiber is attached to the circuit board BD. A pad SG made of a silicone gel commercially available under the designation Hipec is optionally added between the submount soldered photodiode PD at the end of the fiber OF and the circuit board BD. This pad SG protects the arrangement against vibrations in order to prevent damage like fiber breakage or a break of the adhesive joint CG. It does not serve to attach the photodiode to the board but gives additional mechanical support after the fiber with the photodiode attached thereon is fastened on the board. Optical fiber OF in this embodiment comprises also a inner and outer coating which both are removed in the area of adhesive joint CG.

[0022] Figure 5 shows a section taken along line V-V in figure 4. Photodiode PD soldered to submount SM is glued at the end of fiber OF and supported by pad SG on the board BD. Optical fiber OF lies on the board BD in a recess between two lateral posts where it may be secured by any kind of adhesive, for example. The submount SM is contacted with wires to the electrical components on circuit board BD.

[0023] In both embodiments, the fiber can be a single-mode or multimode glass fiber.

Claims

1. An arrangement comprising a photodiode (PD) and an optical fiber (OF) wherein the photodiode (PD) is contacted by contact wires (GW) and has its photosensitive surface (PS) attached directly to one end of the optical fiber (OF) by an optically transparent adhesive (CG).
2. An arrangement as claimed in claim 1 wherein the adhesive (CG) has a refractive index of about 1.5.
3. An arrangement as claimed in claim 1 wherein the adhesive (CG) is transparent in the wavelength range between 1300 and 1600 nm.
4. An arrangement as claimed in claim 1 wherein the adhesive (CG) is a cationic epoxy resin which sets by the action of ultraviolet light.
5. An arrangement as claimed in claim 1 wherein the photosensitive surface (PS) has a diameter be-

- tween 30 and 70 µm.
6. An arrangement as claimed in claim 1 wherein the contact wires (GW) are fixed by the adhesive (CG, PG) and protected by the adhesive from being ripped off. 5
7. An arrangement as claimed in claim 1 wherein the fiber (OF) is fastened on a circuit board (BD), and wherein the contact wires (GW) of the photodiode (PD) are connected to the circuit board (BD), with the adhesive joint (CG) between fiber (OF) and photodiode (PD) representing the only mechanical attachment of the photodiode (PD). 10
8. A circuit board (BD) having an optical fiber (OF) fastened thereon, to the end of which the photosensitive surface of a photodiode (PD) contacted by contact wires (GW) is directly attached by an optically transparent adhesive (CG), the circuit board being fitted with semiconductor components (C1, C2, C3) which form a control circuit for the photodiode (PD), the contact wires (GW) of the photodiode (PD) being connected to the circuit board (BD), and the adhesive joint (CG) between fiber (OF) and photodiode (PD) representing the only mechanical attachment of the photodiode (PD). 15
9. A method of coupling an optical fiber (OF) to a photodiode (PD), comprising the steps of contacting the photodiode (PD) by means of contact wires (GW) and then attaching the photosensitive surface of the photodiode (PD) to one end of the optical fiber (OF) using an optically transparent adhesive (CG). 20
10. A method as claimed in claim 9 wherein the fiber (OF) and the photodiode (PD) are aligned on a three-axis micrometric translation stage and are held in place until the adhesive (CG) has set. 25

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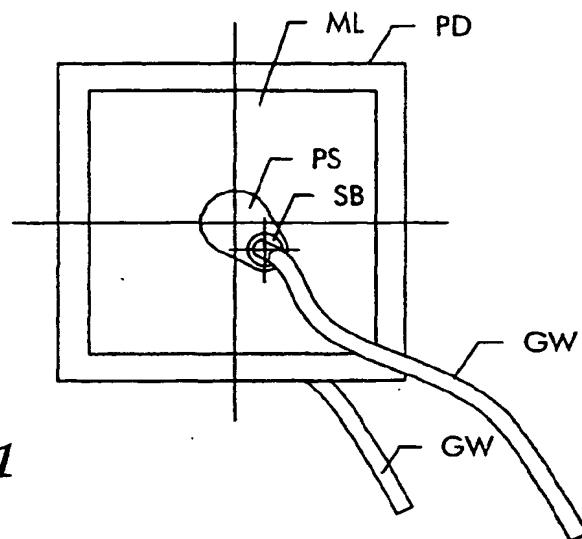


Fig. 1

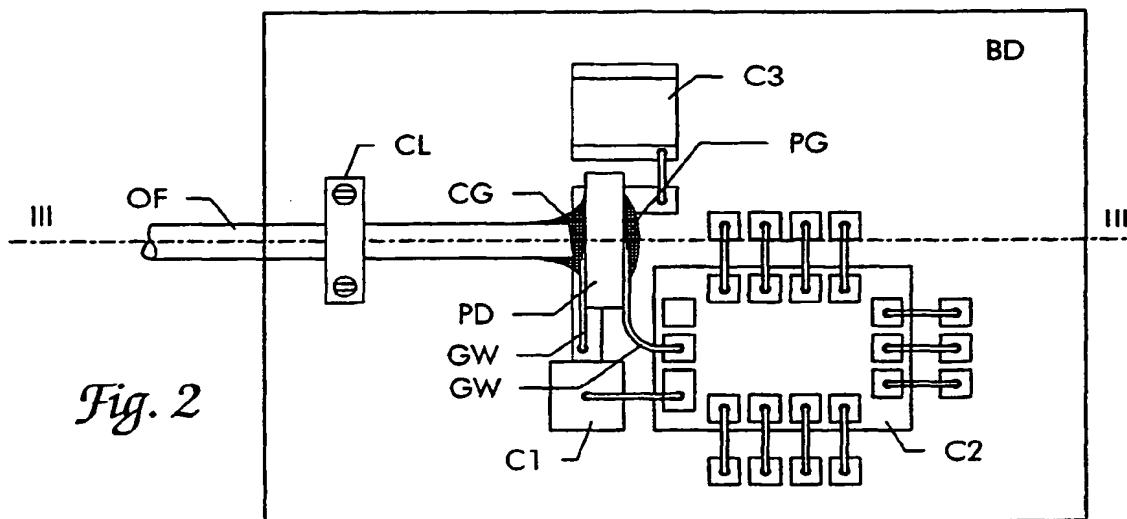


Fig. 2

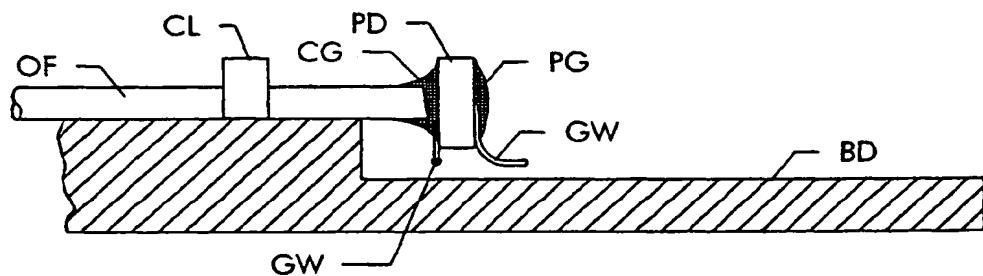


Fig. 3

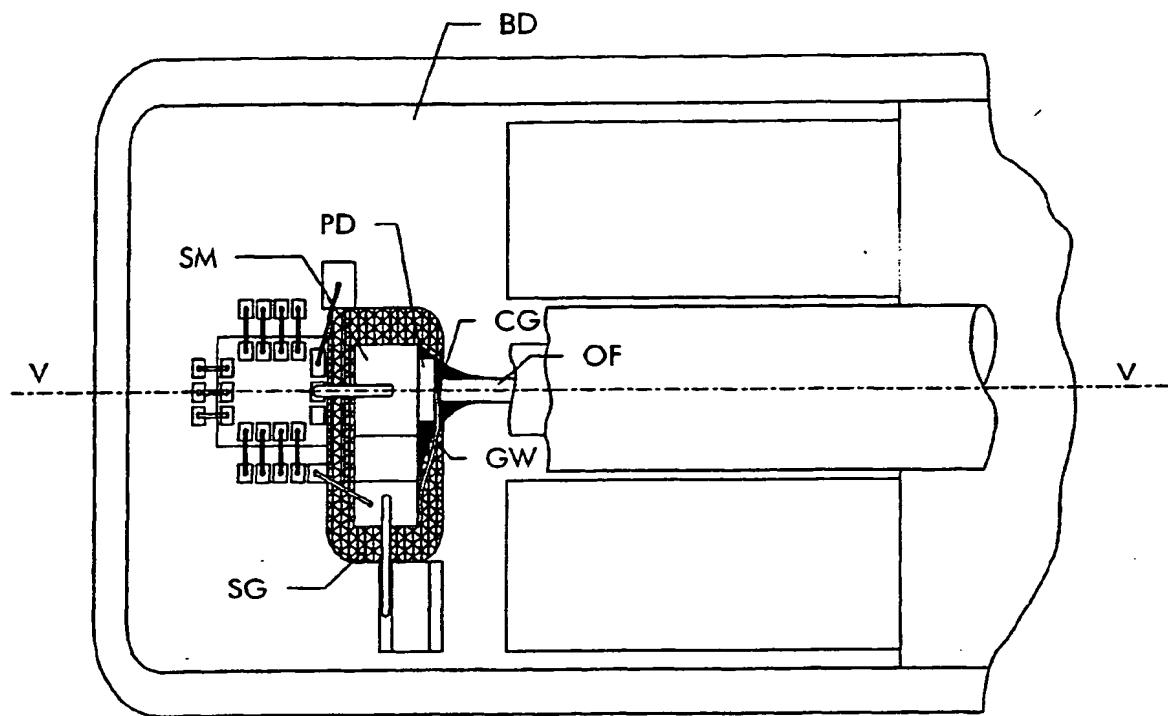


Fig. 4

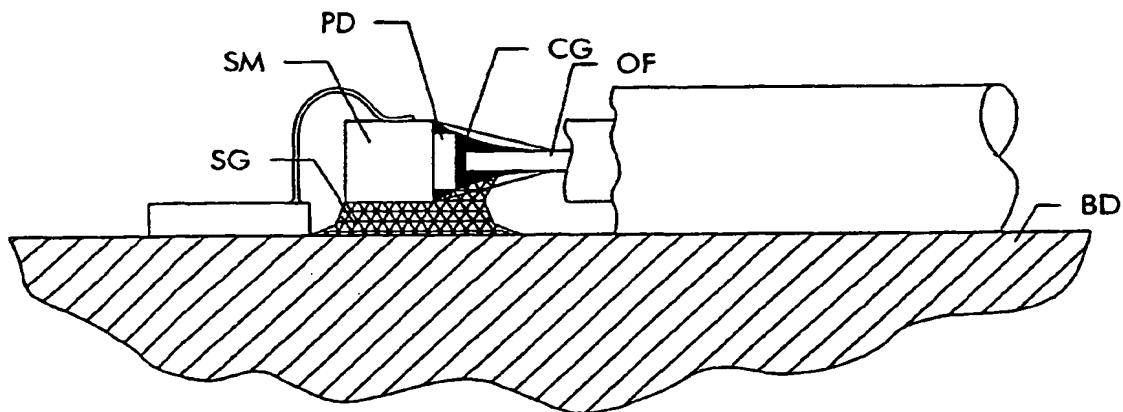


Fig. 5



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EUROPEAN SEARCH REPORT

Application Number
EP 00 44 0129

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	G02B6/42	
X	PATENT ABSTRACTS OF JAPAN vol. 006, no. 132 (E-119), 17 July 1982 (1982-07-17) & JP 57 058369 A (TOSHIBA CORP), 8 April 1982 (1982-04-08) * abstract * <p style="text-align: center;">---</p>	1-4,7-9	G02B6/42	
A	MURATA N: "ADHESIVES FOR OPTICAL DEVICES" PROCEEDINGS OF THE ELECTRONIC COMPONENTS AND TECHNOLOGY CONFERENCE, US, NEW YORK, NY: IEEE, 25 May 1998 (1998-05-25), pages 1178-1185, XP000803697 ISBN: 0-7803-4527-4 * page 1178, right-hand column, paragraph 3 - page 1179, right-hand column, paragraph 2 * <p style="text-align: center;">---</p>	2-4		
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		-/-		
The present search report has been drawn up for all claims				
Place of search	Date of completion of the search	Examiner		
BERLIN	27 October 2000	Ciarrocca, M		
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document		
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DOCUMENTS CONSIDERED TO BE RELEVANT			
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The present search report has been drawn up for all claims			
Place of search	Date of completion of the search	Examiner	
BERLIN	27 October 2000	Ciarrocca, M	
CATEGORY OF CITED DOCUMENTS			
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